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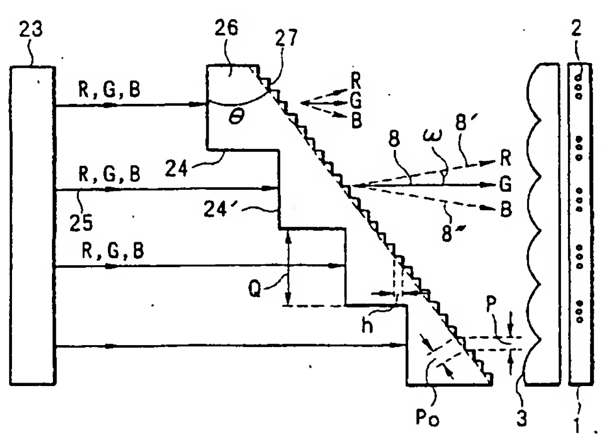
(54) Single plate color liquid crystal display apparatus

(57) White light (25) is input to light diffracting means (26') so composed as to have a structure including macro prisms combined with a lenticular structure and include diffraction gratings at a microscopic level. As the height (h(x)) of unit steps of said diffraction grating (27') is modulated at every period of arranged pixels, the output diffracted light is decomposed into three primary colors (R, G and B), and guided with highly accurate matching to the three respective primary color pixels (2) of a liquid crystal panel means (1). In the pitch modulation type diffraction grating of the prior art, it was basically impossible to avoid the defect that the converged positions of a red light ray (R) and a blue light ray (B) deviate about 30%. In contrast, according to the arrangement of this invention, it becomes possible to eliminate the deviation of the converged positions of not only the green light ray but the red light ray (R) and the blue light ray (B), making it possible to provide a single plate type color liquid crystal display apparatus with high light utilization efficiency.

FIG. 6



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$$\frac{\omega}{\delta_G} \fallingdotseq \frac{\lambda_R - \lambda_G}{\lambda_G} \fallingdotseq \frac{80\ \text{nm}}{530\ \text{nm}} \fallingdotseq 0.15 \tag{4}$$

That is to say, it is known that the magnitude of the G-R separation angle ω is subordinately constrained by the green deflection angle δ_G, and limited to about 15% of δ_G.

On the other hand, attention needs to be paid to a fact that the relation between the diverging angles ε_1 and ε_2 can be obtained by differentiating equation (1).

$$\Delta \sin \alpha_1 + \Delta \sin \alpha_2 = 0 \tag{5}$$

$$\therefore \cos \alpha_1 \Delta\alpha_1 + \cos \alpha_2 \Delta\alpha_2 = 0$$

$$\therefore \frac{\varepsilon_2}{\varepsilon_1} = \left|\frac{\Delta\alpha_2}{\Delta\alpha_1}\right| \frac{\cos \alpha_1}{\cos \alpha_2} \fallingdotseq 1 \text{ for } \alpha_1, \alpha_2 << 1 \tag{6}$$

To separate G ray and R ray, the following condition must be satisfied.

$$\omega > \omega_2$$

$$\therefore \delta > \varepsilon_1 \qquad \cdots\cdots (7)$$

$$\because (6)$$

Generally, according to the law of energy conservation, if the effective surface area of a Lambertian light source is designated by A_0 and the vertical projection of the incident area of the diffracting plate is designated by A_1, the diverging angle ε_1 of the incident light is given by the following expression.

$$\varepsilon_1 \fallingdotseq 2\sqrt{\frac{A_0}{A_1}} \tag{8}$$

$$\therefore \varepsilon_{1MAX} > 2\sqrt{\frac{A_0}{A_1}} \tag{9}$$

If the diverging angle distribution is uniform, equation (8) holds. In actuality, however, the diverging angle distribution is not uniform, so that inequality (9) holds. Normally, the maximum value ε_{1MAX} of ε_1 is about 1.5 times as large as ε_1 in most cases. The minimum projection light source proposed as a test case in the past is about 1.4 mmϕ and therefore the surface area is π (1.4 mm)^2, namely, about 6.3 (mm)^2. The surface area of the ordinary projection light source is about 25 (mm)^2. On the other hand, the area of the diffracting plate is substantially equal to the area of the liquid crystal panel, and the diffracting plate of the maximum size for projection use has an opposite angle of about 6.5" and an area of 13,000 (mm)2. By substituting those values into expression (9), we have the following expression.

$$\omega > \varepsilon_{1MAX} \fallingdotseq 3\sqrt{\frac{A_0}{A_1}} \fallingdotseq 0.07 - 0.14\ \text{[rad]} \tag{10}$$

$$\frac{P_{01}}{P_{03}} \doteqdot 1.6 \qquad (15)$$

By the above analysis, the following could be clarified. Specifically, if the pitch of the diffraction grating is modulated in synchronism with the period of trio pixel array to satisfy equations (13) and (14), the diffraction grating 6' can be made to also play the role of the three-position means 3 in Fig. 2 so long as G ray is concerned. With this, description of the result of clarification by the present inventor of the principles of the conventional techniques related to Item 3.3 in Fig. 1 is finished.

As the second step, description will proceed to the conventional technique in Item 3.3 in Fig. 1. In the macroscopically flat plate diffraction grating, there is a condition of constraint shown in equation (4), which has been described above. From equations (4), (1) and (15), it is inevitable that an unfavorable expression given below holds.

$$\frac{\omega_{01}}{\omega_{03}} \doteqdot \frac{P_{01}}{P_{03}} \doteqdot 1.6 \qquad (16)$$

In the above equation, ω_{01} and ω_{03} are R-G separation angles by those portions of the diffraction grating which correspond to δ_1 and δ_3 in Fig. 4. The relation represented by the above expression is shown in Fig. 5.

If in the above expression the value is 1.0 instead of 1.6, all three rays, including the red ray and the blue ray, besides the green ray, are matched (coincide) with the liquid crystal elements. However, because the above value is 1.6, the red ray and the blue ray are not matched with the target liquid crystal elements as shown in Fig. 5. In other words, the utilization efficiency of the red and blue light ray deteriorates.

Fig. 5 shows only one period of the trio pixel array. In Fig. 5, reference numerals 2 and 6' denote same things as already described, 14, 15 and 16 denote the first order diffracted G rays, 17, 18 and 19 denote the first order diffracted R rays, and 20, 21 and 22 denote the first order B rays. As is clear from Fig. 5, R and B component rays of the principal ray striking the center of each pitch of the diffraction grating 6' are both correctly incident on the target pixels. On the other hand, the marginal rays corresponding to both end portions of each pitch are unable to be incident on the target pixels due to deviation loss. Therefore, in the techniques (B) and (D) in the prior art, the problem has become evident that the convergence of R and B rays to the red and blue pixels by the diffraction grating is not compatible as mentioned in Item 3.4 in Fig. 1. More specifically, the problem includes the deterioration of the transmission efficiency of R and B rays and the deterioration of chromatic purity owing to color mixture.

In the course of the above description, the constraint on the size of a usable light source was mentioned, and it is vitally important to take this constrain into consideration.

This is because not only a point light source such as can be expressed as a mathematical concept of a point does not exist in reality, but it should be understood that a point light source is incapable of existing according to the principle of uncertainty or the second law of thermodynamics. A premise including only one wrong hypothesis would lead to illusions such that innumerable impossibilities are taken for possibilities. For example, if a viability of a point light source is supposed, from this it may be deduced that thermonuclear power generation can be realized easily.

Therefore, the above-mentioned constraint on the size of the light source is an important matter requiring consideration.

The present invention could not have been possible without the above-mentioned result of clarification by the present inventor. On account of this, this subject will first be summarized in the following.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a single plate type color liquid crystal display apparatus featuring the improved transmission efficiency.

Another object of the present invention is to provide a liquid crystal display capable of having the deflection angle δ_G by the light diffracting means of 10 (0.17 rad) or less and the R-G separation angle ω of 3° (0.05 rad) or larger (in other words, thus overcoming the constraint by equation (4)).

A further object of the present invention is to provide a novel optical system capable of make compatible the convergence by the light diffracting means of rays to the target R, G and B pixels (thus overcoming the constraint in equation (16)).

Yet another object of the present invention is to provide a new-fangled optical system for reducing nearly in half a substantial increase of the light diverging angle caused by the R-G separation angle by the light diffracting means.

A still further object of the present invention is to provide a liquid crystal display apparatus for improved picture qual-

Fig. 14 is a schematic structure diagram showing an eighth embodiment (Type II) including macro lenticular light diffracting means according to the present invention;

Fig. 15 is a fragmentary view, on an enlarged scale, of Fig. 14;

Fig. 16 is a schematic structure diagram showing a ninth embodiment (Type II) including macro lenticular light diffracting means according to the present invention;

Fig. 17 is a schematic structure diagram showing a tenth embodiment (Type II) including macro lenticular light diffracting means according to the present invention;

Fig. 18 is a graph showing the applicable range of the eighth and ninth embodiments according to the present invention;

Fig. 19 is a schematic structure diagram showing an application of the present invention to a projection type display apparatus; and

Fig. 20 is a schematic structure diagram showing an application of the present invention to an optical fiber display apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 6 shows a first embodiment of the present invention.

In Fig. 6, reference numeral 1 denotes the single plate type color liquid crystal panel means already mentioned, 3 denotes the three-position means already mentioned, 23 denotes the block including a light source and collimator means already mentioned, 25 denotes a white ray, 26 denotes macro prism type diffracting means including at a macroscopic level prisms and at a microscopic level a diffraction grating formed on the oblique side face of each prism. Reference numeral 27 denotes a diffraction grating, θ denotes the vertical angle of the macro prism, P_0 denotes the pitch of the diffraction grating array, P denotes the projection of P_0 as viewed from the emerging direction of the first order diffracted ray, that is, the projection of the pitch which is measured at right angles with the traveling direction of the light, and which is substantially equal to $P_0\cos\theta$. The h denotes the height of a unit step as a component part of the diffraction grating, 24 and 24' denotes the side faces of the row of prisms, the respective side faces 24 and 24' being so arranged as to be substantially parallel with or at right angles with the incident white light 25. The Q denotes the arraignment pitch of the row of macro prisms as viewed from the direction of the incident light, in other words, the projection of the pitch in the direction at right angles with the light traveling direction. The 8, 8' and 8" denotes G, R and B rays of the first order diffracted output rays, and ω denotes the R-G separation angle. The operation principle of this embodiment will be described using the following expressions.

$$(n - 1)h = \lambda_0 \tag{17}$$

$$P \fallingdotseq \frac{\lambda_R - \lambda_G}{\omega} \fallingdotseq \frac{80\ \text{nm}}{\omega} \tag{18}$$

$$Q > 100\,\lambda_G \fallingdotseq 53\ \mu\text{m} \tag{19}$$

$$\frac{|\lambda_0 - \lambda_G|}{P} < \frac{10°}{57.3°} \fallingdotseq 0.17 \tag{20}$$

$\therefore$

$$|\lambda_0 - \lambda_G| < 0.17P = 0.17\,\frac{80\ \text{nm}}{\omega} \fallingdotseq \frac{13\ \text{nm}}{\omega} \tag{21}$$

$$\therefore \text{ If } \omega \fallingdotseq 0.05\ \text{rad},\ |\lambda_0 - \lambda^G| < 260\ \text{nm} \tag{22}$$

In equation (17), λ_0 denotes the characteristic wavelength of this system, n denotes the refractive index of the medium forming the macro prism type light diffracting means. The first order diffracted ray of wavelength λ_0 passes at zero deflected angle through the light diffracting means. This is because the effective optical path difference at each unit step of the diffraction grating is a difference of (n-1)h between nh in the medium and h in the air and the difference is equal to wavelength λ_0 according to equation (17). Fig. 6 exemplifies a case where λ_0 is equated with λ_G. The λ_R, λ_B or any specific wavelength of the infrared or ultraviolet region can be selected for the λ_0 in a range that the selected wavelength satisfies equation (21).

$$\therefore\ \omega = T/3\left(\frac{D_0}{n} + D_{(x)} - D_0\right) \tag{26}$$

$$Q > 53\ \mu m \tag{19}$$

In the above equations, L denotes integers of 1 to 3, n denotes the refractive index of the medium of the liquid crystal panel means and the light diffracting means, and D_0 denotes the distance from the surface of the liquid crystal panel means to the row of pixels. The symbol T denotes the trio pixel period, P(x) denotes the projected pitch (the pitch measured in the direction at right angles with the light traveling direction), λ_R and λ_G denote wavelengths of R and G rays, and δ_G denotes the deflected angle of G ray.

Equation (23) shows the condition for setting the effective optical path difference (n - 1)h(x) of each step of the grating for G ray so that the L-th order diffracted G ray travels in the direction of the G pixel. The denominator, $D_0/n + D(x) - D_0$, of the last term of equation (23) is the effective optical path length from the diffraction grating to the pixel row of the liquid crystal panel, and the numerator x is the distance in the x direction measured from the center of the G pixel. The ratio between them is equal to the deflected angle δ_G of G ray.

(Equation (24))

Equation (25) shows the condition for making the R-G separation angle equal to ω. Inequality (19) has already been described.

Reference numeral 28 indicates that face 24' and face 27' may be reversed. This holds for Fig. 7. As is clear from the above description, according to this third embodiment, the defects in Item 3.4 in the prior art can be overcome.

Nevertheless, the diverging angle of output from the liquid crystal panel in the third embodiment has a large value of 5 ω as shown in Fig. 8. This vale is equal to the output diverging angle of 5 ω in the prior art in Fig. 5 and corresponds to the total value of ±ω and ±1.5 ω in Fig. 4. A fourth embodiment for decreasing the output diverging angle to about 3 ω is shown in Fig. 9.

In Fig. 9, reference numerals other than 4 designate the same things as shown in Fig. 8., 4 denoting lenticular lenses forming the divergence-reducing collimator means. The focal plane of the collimator means is selected so as to substantially coincide with the diffraction grating face 27' (accuracy within ±30%). For clarity of illustration, the height ΔD of the macro prism is expressed so to be about the same as the distance to the pixel face, D_0, but in actuality ΔD is less than about 1/5 of D_0. Therefore, the above setting is possible. By the work of the collimator means 4, the light rays emerging from the same point of the diffraction grating face 27', regardless of their direction, become parallel rays when they are output from the collimator means. Therefore, the ray emerging from each center 30 of the macro prism face, namely, the principal ray is converted into parallel rays perpendicular to the liquid crystal panel face. The marginal rays 30' and 30" are converted respectively into parallel rays at angles of ±1.5 ω to the normal of the liquid crystal panel. Consequently, the diverging angle of output rays from the panel is reduced to about 3 ω (reduced to about a half of 5 ω). With this, description of Fig. 9 is finished. A fifth embodiment by which to further reduce the diverging angle is shown in Fig. 10.

In Fig. 10, 31 denotes black stripe means, which are formed right behind the light output face of or on the light input face 24' of the light diffracting means 26' as indicated by 31". Faces 24" are located along the light traveling direction and may be formed inclined as illustrated. (In some cases, the faces 24" thus inclined facilitate the manufacture of the light diffracting means 26'.) The parts other than mentioned in this paragraph are the same as those shown in Fig. 9.

If the width of the black stripes is set to be about 2/3 of the trio pixel period T, the diverging angle of the emerging rays from the liquid crystal panel can be reduced to 2/3 that of the case where no black stripes are used, more specifically, reduced to about 2 ω as shown in Fig. 10.

According to the fifth embodiment, the light transmission efficiency is reduced in proportion to the black stripe rate, but the diverging angle of the output light can be decreased, and owing to the color mixture prevention and the improved contrast ratio, the picture quality improves. Note that the fifth embodiment comprises single plate type color liquid crystal panel means, three-direction means, three-position means, and black stripe row means, in other words, the diffraction grating is not a requirement. With this, description of Fig. 10 is finished. The above-described embodiments are of a type using the pixel array of a trio of RGB, RGB, and so on. Description will now be made of an applied example using a quad type pixel array of RGBG, RGBG and so on.

Fig. 11 shows a quad type applied example as a sixth embodiment of the present invention. In Fig. 11, reference numeral 27" denotes diffraction gratings formed on oblique side faces of the macro prisms, which are inclined in the reverse direction to the gratings 27' already described, and 2' denotes a row of quad-arranged pixels. As is obvious from the arrow marks of the light rays, according to this sixth embodiment, the color rays can be collected to the quad-arranged pixels.

As is well known, the brightness contribution rates of the R, G and B component rays forming a white ray are

$$g \fallingdotseq \frac{n}{n-1}\,\alpha'_1 \qquad (34)$$

$$\tan\beta = \frac{n\sin\alpha'_1 - \sin\alpha_G}{n\cos\alpha'_1 + \cos\alpha_G} \qquad (35)$$

In the above equation, equations (25') and (26) are the same as equations (25) and (26) mentioned above. Equation (27), which indicates the output direction of G ray, is the same as equation (24) mentioned above. The left side member ($nh_1 - h_2$) of equation (28) expresses the effective optical path difference at each step of the diffraction grating.

Therefore, according to equation (33), by periodically modulating the effective unit optical path difference as a function of x, the G output rays can be directed toward the G pixels. This modulation can be achieved by keeping compatibility with the constraint condition equation (25') showing the definition of the R-G separation angle. Therefore, Items 3.3 and 3.4 in Fig. 1 already described can be satisfied at the same time. Equation (34) shows the condition to be satisfied by the prism faces 32" and 34. Equation (35) is a condition for specifying the microscopic-level prism angle of the diffraction grating. To satisfy this condition is effective for increasing the diffraction efficiency close to 1.

With the above, description of Figs. 12 and 13 is finished.

Fig. 14 shows an eighth embodiment of the present invention, which belongs to Type II in Fig. 1 already mentioned. In Fig. 14, the parts designated by 1, 2, 25, 32, 32', 32", 34, and 35 are the same as have been described above, 33' denotes light diffracting means has a lenticular structure at its macroscopic level, and includes diffraction gratings at its microscopic level, 36' denotes a dotted line indicating the macro lenticular shape, and 37' denotes diffraction gratings. Fig. 15 is a fragmentary view on an enlarged scale.

In Fig. 14, each lens formed by combining a prism face 34 and a macro lenticular shape 36' is a macro lenticular lens. A diffraction grating 27 may be joined with an adhesive to the outer surface of the macro lenticular shape 36'.

The equations expressing conditions in the eighth embodiment are as follows.

L1, 2, 3

$$P_{(x)} = \frac{80\text{ nmL}}{\omega} = \frac{3\left(\frac{D_0}{n} - D_0 + D_{(x)}\right)}{T}\,80\text{ nmL} \qquad (25)$$

$$\alpha_G = \frac{x}{\frac{D_0}{n} - D_0 + D_{(x)}} \qquad (27)$$

$$np\tan(\theta - \alpha'_1) - p\tan\theta = p\,\alpha_G - L\lambda_G \qquad \ldots\ldots (36)$$

$$\fallingdotseq (-n\tan\alpha'_1 + n\,\theta\sec^2\alpha'_1 - \theta)P$$

$$\therefore\quad \theta_{(x)} = \frac{1}{n\sec^2\alpha'_1 - 1}\left\{\alpha_G + n\tan\alpha'_1 - \frac{L\lambda_G}{P}\right\}$$

$$\ldots\ldots (36')$$

$$\theta_{(o)} = \alpha_{G(o)} = 0$$

sated.

In a direct viewing type liquid crystal display, a line light source is normally used for the light source means in the block 23. The collimator means is formed by combining a light guide plate, a row of prisms, black stripes, lenticular lenses, and so on. In such an application as this, the present invention can be applied if about 0.3 to 0.6 rad is selected for the value of the R-G separation angle ω. With this, description of the preferred embodiments of the present invention is finished.

In the embodiments from Fig. 8 onwards, which belong to Type II of the present invention, the array pitch of macro lenticular elements is substantially equal to the array pitch of the liquid crystal panel means. Therefore, the thermal expansion coefficients of the materials need to be matched to that of the liquid crystal panel means. The liquid crystal panel means is normally made of a glass material. Accordingly, in the embodiments of the present invention, too, a glass material is ordinarily used as the material of the macro lenticular type light diffracting means. The diffraction grating and the lenticular elements provided at the surface of the macro lenticular type light diffracting means are formed of a glass or resin material, but for general applications, a ultraviolet-light-hardening type resin material is recommended.

In the above presentation of the embodiments of the present invention, description has been made on the assumption that there is air in the spaces between the different components.

However, those spaces may be filled with a resin material having a smaller refractive index than that of the components of the embodiment. In this case, each embodiment can be formed by taking into consideration a fact that the effective optical path difference $nh_1 - h_2$ changes to $nh_1 - n_2h_2$.

The liquid crystal display apparatus according to the present invention is not limited to the direct viewing type, but may be applied to the projection type and the optical fiber type. Fig. 19 shows an application of the present invention to the projection type display. In Fig. 19, reference numeral 40 denotes a block, typical of the embodiments described above, which includes the above-mentioned macro prism type or macro lenticular type light diffracting means in the present invention. Reference numeral 23 denotes a block including light source means and collimator means, 1 denotes liquid crystal panel means, 41 denotes projection lens means, and 42 denotes screen means.

Fig. 20 shows an application of the present invention to the optical fiber type display. In Fig. 20, reference numeral 43 denotes optical fiber, 44 denotes a fiber light input end, and 45 denotes a fiber light output end plus fiber screen means.

When a liquid crystal panel utilizing the polarization of light is applied, in every embodiment, the use of P wave (equivalent to E_y wave, or TM wave in the field of electric wave, is not essential but is recommended. The reason is that the interface reflection loss of P wave is, as is well known, smaller than that of S wave, which makes it possible to construct a high-efficiency optical system. With this, the introduction of the embodiments and applications of the present invention is finished.

According to those embodiments of the present invention, there is provided a single plate type color liquid crystal display apparatus with improved light transmission efficiency, which is capable of separating the input white light into three primary colors traveling in different directions, and guiding the three color rays to the corresponding pixels of the single plate liquid crystal panel means.

According to the first (Fig. 6) and the second (Fig. 7) embodiments of the present invention, it is possible to set the R-G separation angle by the light diffracting means at 0.05 rad or more and the deflected angle of the green ray at 0.17 rad or less, making it possible provide a compact optical system.

According to the third to tenth embodiments of the present invention, it is possible to achieve the compatibility of the converging actions by the light diffracting means into the R, G and B pixels, with the result that a liquid crystal display apparatus can be provided which has reduced color mixture, hence high picture quality, and less required power consumption.

To be more specific, as against the deterioration ratio of the light converging action of about 1.6 in the prior art, according to Type II in the present invention, that deterioration ratio can be reduced to about 1.4 or less, so that the utilization efficiency of R and B rays is thereby improved.

Claims

1. A single plate type color liquid crystal display apparatus having light source means (23), collimator means (23), and single plate type liquid crystal panel means (1), comprising:

   light diffracting means (27) arranged between said collimator means (23) and said single plate liquid crystal panel means (1); and
   three-position means,

   wherein said light diffracting means (27) is, at a macroscopic level, in a three-dimensional unflat plate form with a macro periodic structural pitch and additionally has at least either a macro-prism shape or a macro lenticular shape, and also includes a multistepped diffraction gratings (27) at a microscopic level, wherein the macro periodic pitch is larger than 53 μm, wherein input white light is, when it becomes diffraction output,

FIG. 1

COMPARISON OF THE PRESENT INVENTION WITH PRIOR ART

	THIS INVENTION TYPE (I)	THIS INVENTION TYPE (II)	Ⓐ USP 5,355,189 USP 5,537,171	Ⓑ JP-A-6-230384	Ⓒ B.A.Loiseaux.et. a1 Asia Display. '95. P87-89	Ⓓ N.Ichikawa Asia Display. '95. P727-729	Note
1. OBJECT IMPROVE LIGHT UTILIZATION IN A SINGLE PLATE COLOR LIQUID CRYSTAL DISPLAY.	○	○	○	○	○	○	○ (YES)
2. MEANS 2.1 DIFFRACTING PLATE MEANS FLAT AT MACRO LEVEL, WITH DIFFRACTION GRATING AT MICRO LEVEL.	×	×	○	○	○	○	× (NON)
2.2 LIGHT DIFFRACTING MEANS IN 3-D UNFLAT PLATE AT MACRO LEVEL WITH DIFFRACTION GRATING AT MICRO LEVEL	○	○	×	×	×	×	△ INSUFFICIENT
2.3 LIGHT-DIFFRACTING MEANS IN PRISM SHAPE AT MACRO LEVEL, WITH DIFFRACTION GRATING AT MICRO LEVEL	○	—	×	×	×	×	—
2.4 LIGHT DIFFRACTING MEANS LENTICULAR AT MACRO LEVEL, WITH DIFFRACTION GRATING AT MICRO LEVEL	—	○	×	×	×	×	
3. FUNCTION 3.1 DIFFRACTION GRATING ORIENTS THREE PRIMARY COLORS TO THREE DIRECTIONS.	○	○	○	○	○	○	
3.2 DEFLECTING ANGLE OF G RAY BY DIFFRACTING MEANS: 10 MAX. (COMPACTNESS)	○	—	×	×	×	×	
3.3 CONVERGENCE OF G RAY BY DIFFRACTING MEANS.	×	○	×	○	×	○	
3.4 CONVERGENCE OF R, G AND B RAYS BY DIFFRACTING MEANS TO RESPECTIVE PIXELS HAS BEEN MADE COMPATIBLE.	×	○	×	△	×	△	

FIG. 4

PRIOR ART

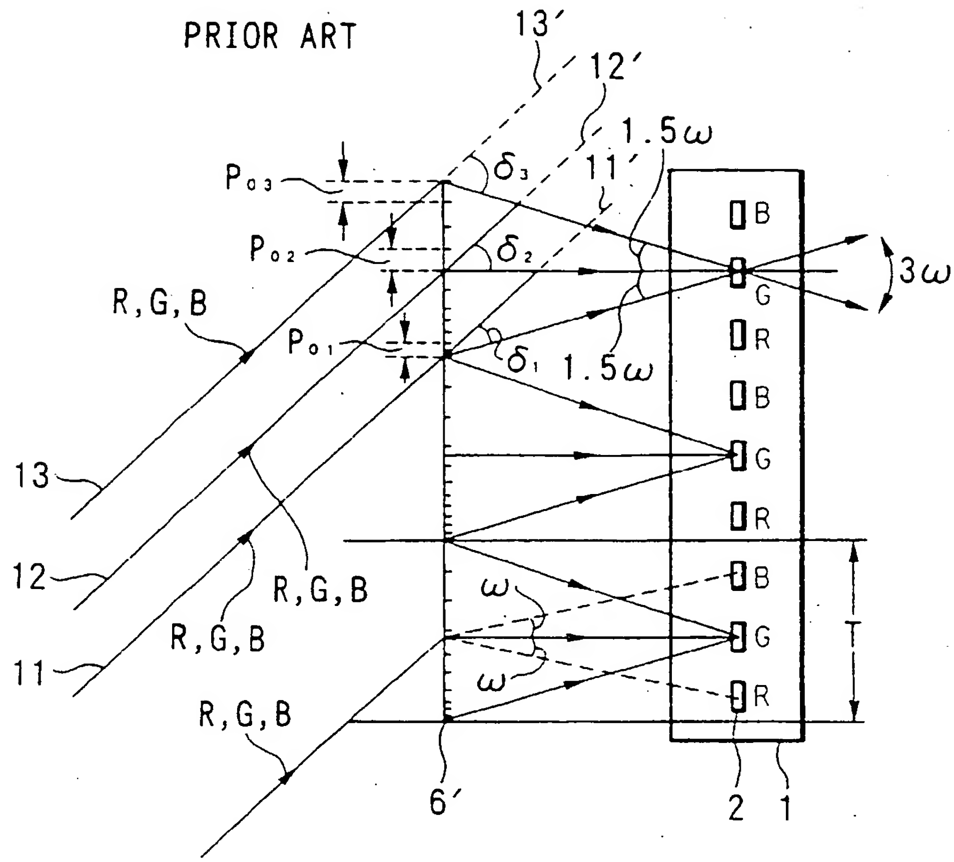


FIG. 5

PRIOR ART

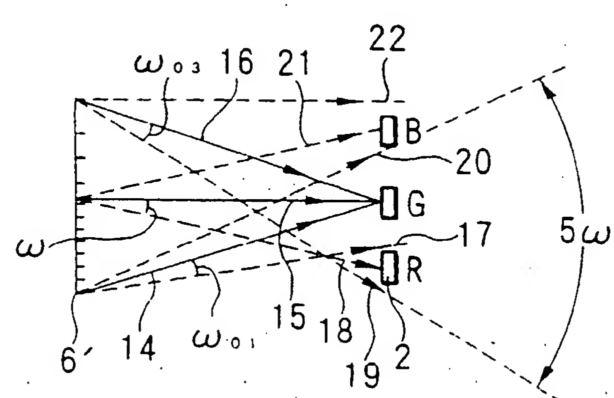


FIG. 8

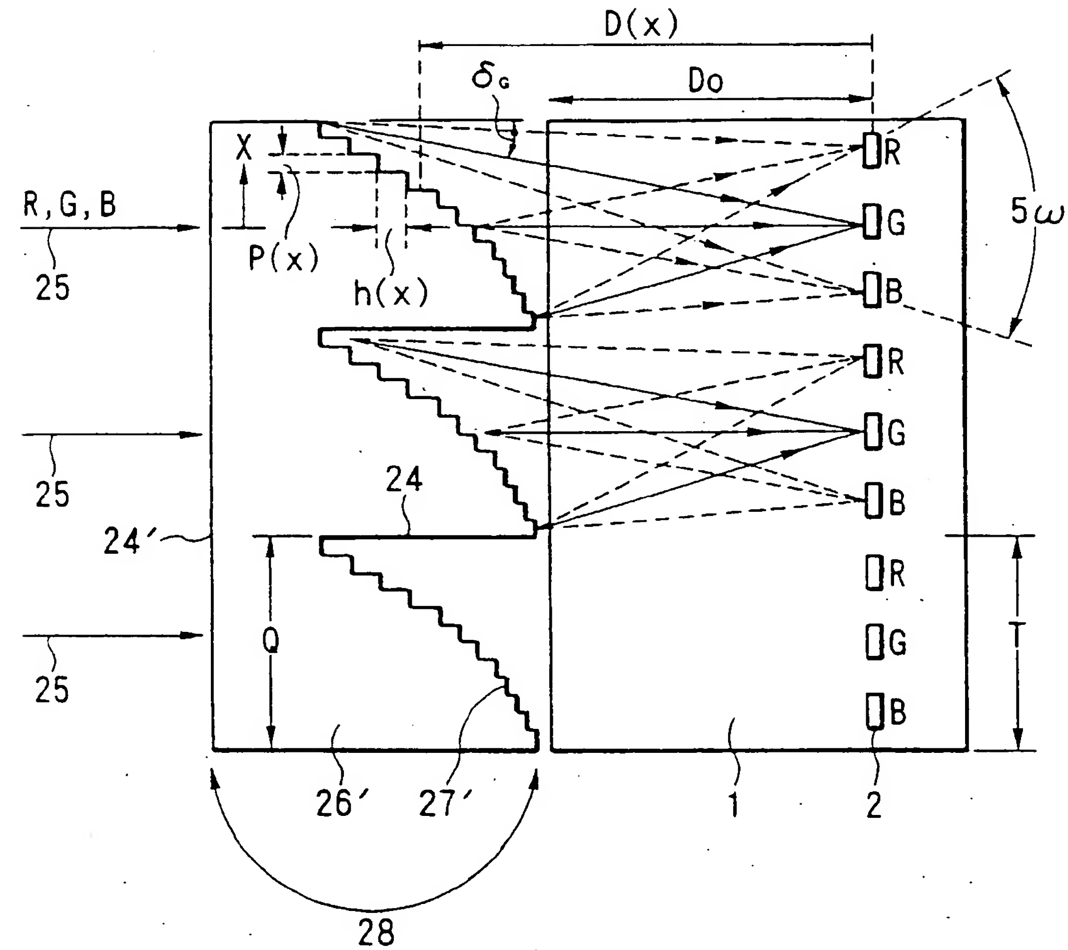


FIG. 10

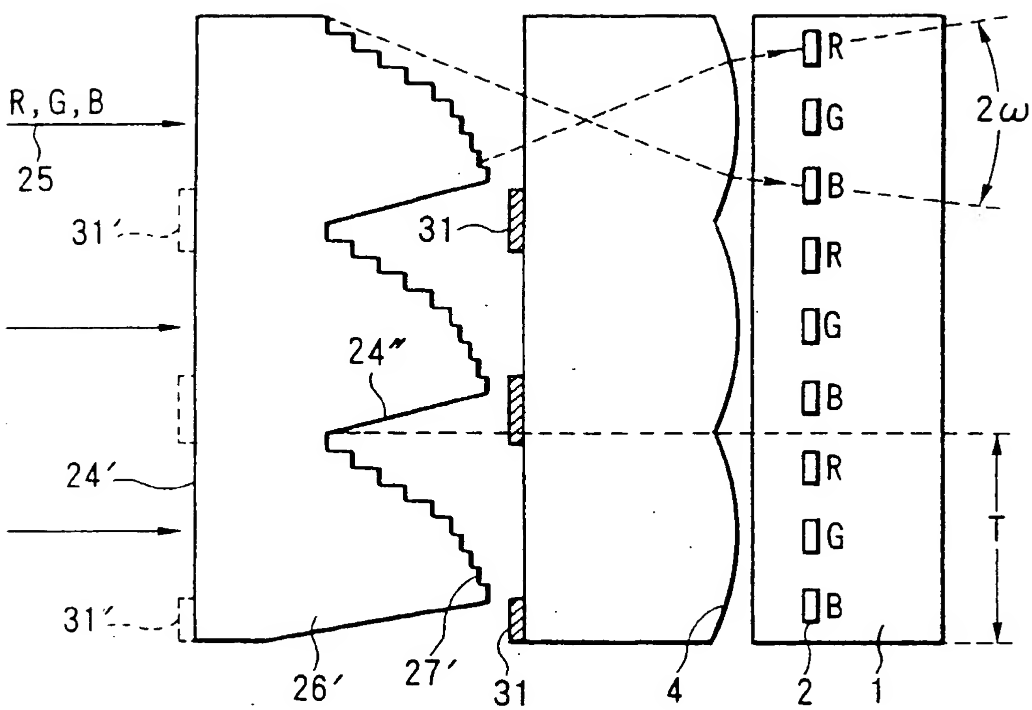
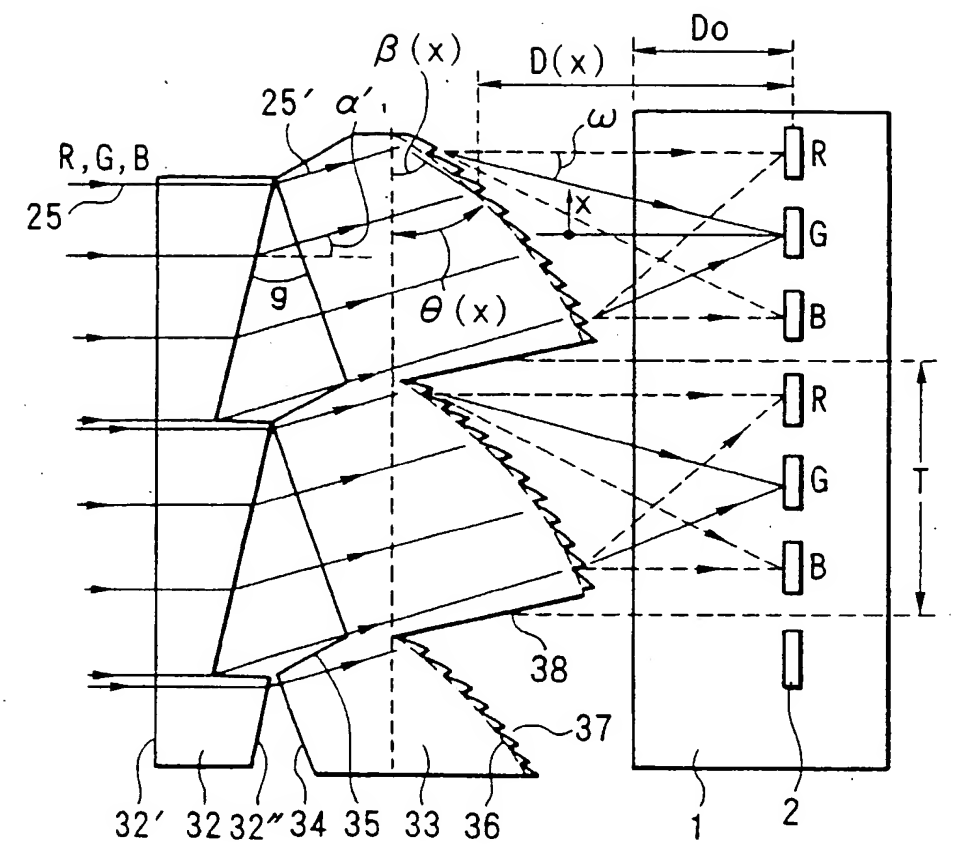


FIG. 12


β(x)
Do
D(x)
25′ α′1
ω
R,G,B
25
R
G
B
R
G
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θ(x)
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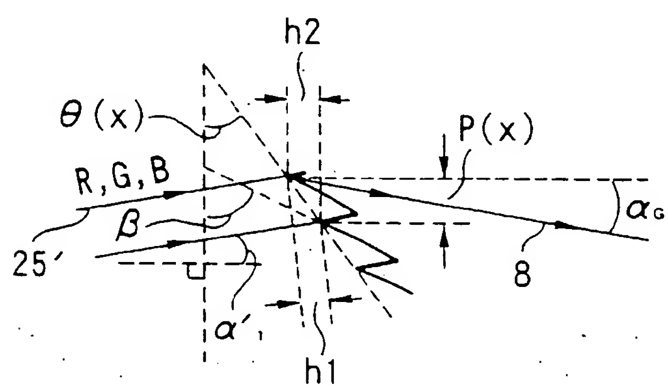
38
37
32′ 32 32″ 34 35 33 36
1 2

FIG. 13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θ(x)
P(x)
R,G,B
β
αG
25′
8
α′1
h1

FIG. 16

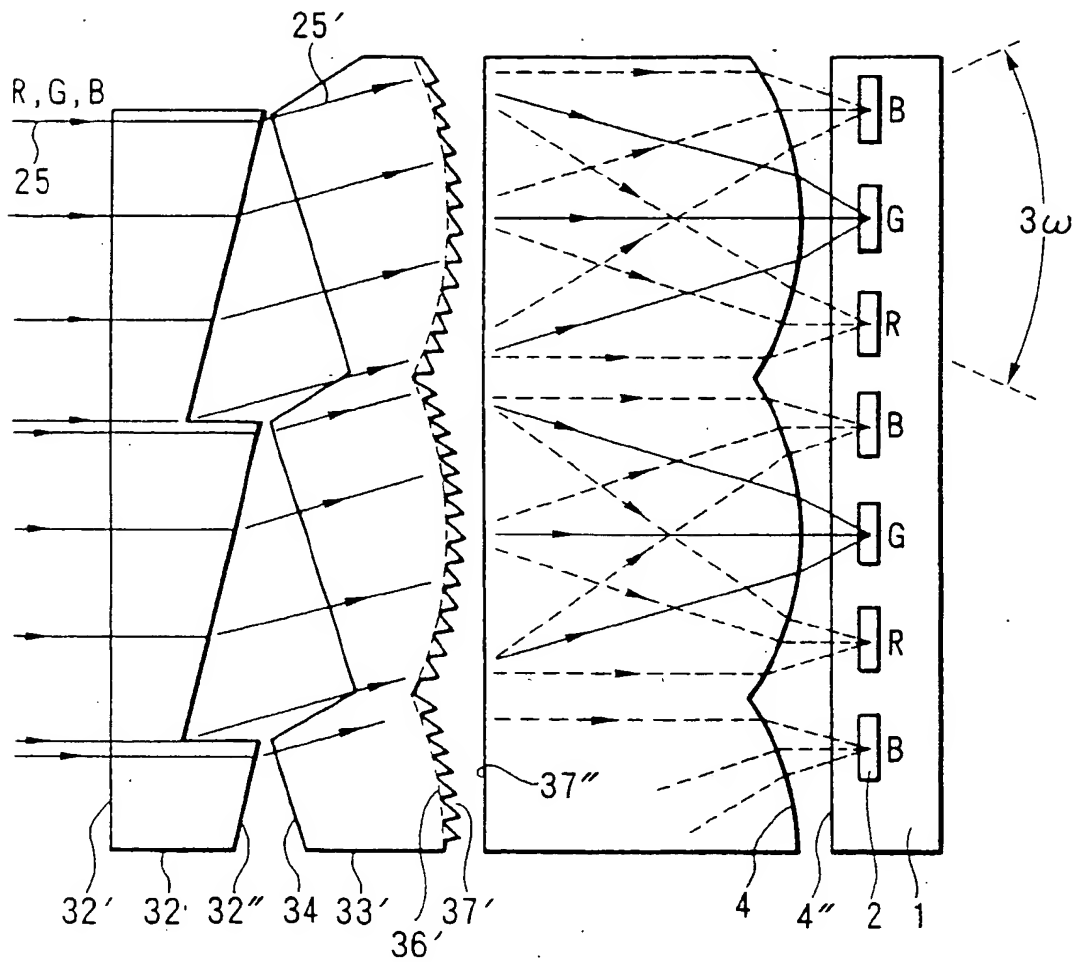


FIG. 18

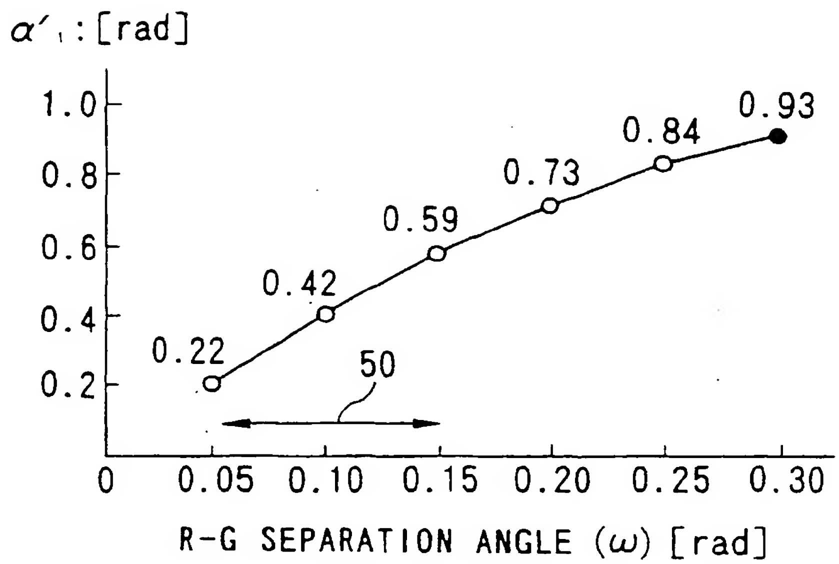
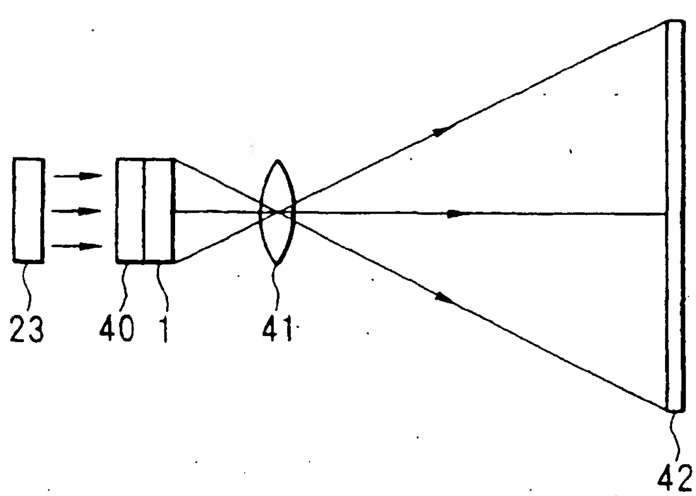

α'₁ : [rad]
1.0
0.8
0.6
0.4
0.2
0.93
0.84
0.73
0.59
0.42
0.22
50
0
0.05
0.10
0.15
0.20
0.25
0.30
R-G SEPARATION ANGLE (ω) [rad]

FIG. 19


23
40
1
41
42

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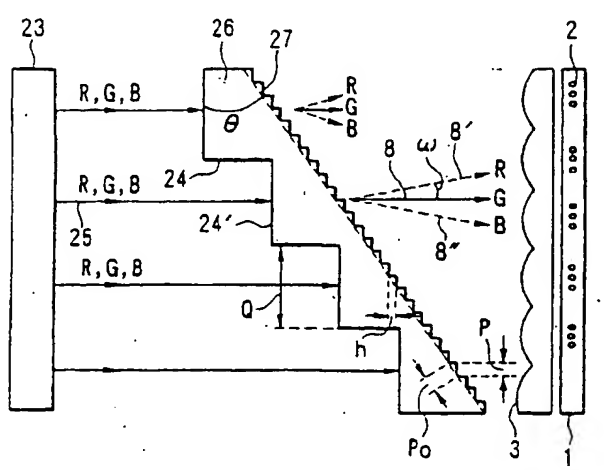
(54) **Single plate color liquid crystal display apparatus**

(57) White light (25) is input to light diffracting means (26') so composed as to have a structure including macro prisms combined with a lenticular structure and include diffraction gratings at a microscopic level. As the height (h(x)) of unit steps of said diffraction grating (27') is modulated at every period of arranged pixels, the output diffracted light is decomposed into three primary colors (R, G and B), and guided with highly accurate matching to the three respective primary color pixels (2) of a liquid crystal panel means (1). In the pitch modulation type diffraction grating of the prior art, it was basically impossible to avoid the defect that the converged positions of a red light ray (R) and a blue light ray (B) deviate about 30%. In contrast, according to the arrangement of this invention, it becomes possible to eliminate the deviation of the converged positions of not only the green light ray but the red light ray (R) and the blue light ray (B), making it possible to provide a single plate type color liquid crystal display apparatus with high light utilization efficiency.

FIG. 6



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12-02-1999

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